Intraoperative Autotransfusion

Experience in 725 Consecutive Cases

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Autologous intraoperative transfusion employing the Haemonetics Cell Saver® is reported in 725 patients from a general hospital population, of which 75% were cardiovascular patients. The remaining cases included various orthopedic procedures, splenectomy, craniotomy, ectopic pregnancies, Caesarian sections, and exploratory laparotomy. On occasion, this method was utilized in trauma and in pediatric surgery.

The product of washed red blood cells gave an average yield of 573 cc per case with an average hematocrit of 55 cc/dl available for autologous infusion. In 100 consecutive open heart procedures operated prior to the Cell Saver period, an average of 1.97 units of bank blood was utilized during operation, as compared with 0.75 units in 100 consecutive cases studied employing the Cell Saver ($p < 0.0001$). Homologous blood utilization during cardiac surgery declined more than 50% with the use of the Cell Saver. Quality control was monitored scrupulously and included special precautions against air embolism, abnormal coagulation, and sepsis. The overall mortality rate was 2.8%, and in no instance was mortality or morbidity ascribable to the autologous transfusion.

Numerous advantages offered by autotransfusion include prevention of sensitization of the recipient to various antigens in donor erythrocytes, leucocytes, platelets, and plasma, and avoidance of transfusion-transmitted diseases, especially viral hepatitis. Additionally, autologous blood, the only perfectly compatible product, provided immediate availability while conserving blood bank resources. In circumstances in which the intraoperative blood loss exceeded 1000 cc in the adult, its use was observed to be cost-effective. In the present study, autotransfusion proved safe, efficient, and in some instances life saving.

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CURRENT MEASURES to reduce the transfusion requirements of homologous blood products for patients undergoing elective and emergency procedures have resulted in the utilization of various blood-saving apparatuses and systems. For more than a decade, intraoperative transfusion of whole blood, shed during surgery or following trauma, has been utilized for a variety of reasons, the principal of which was the unavailability of bank blood during a massive hemorrhage. Additional advantages are the avoidance of transfusion-induced viral hepatitis, alloimmunization, hemolytic, and allergic reactions from homologous donor products, and the conservation of bank blood.[1-5] Adverse sequelae, however, have been significant, and include hemolysis, coagulopathy, air embolism, and renal failure, initiated with autologous transfusions employing more primitive systems devoid of the technologic advances currently available.[6,7,8]

The introduction of the Haemonetics Cell Saver® (Haemonetics Corporation, Braintree, MA) in 1976 obviated many of these serious complications. This technique allows the recovery of blood from the operative site and its efficient processing as washed packed erythrocytes ready for reinfusion within minutes of collection.

The present study is a retrospective review of 725 surgical cases, in which intraoperative autologous transfusion was accomplished using this instrument.

Materials and Methods

Seven hundred twenty-five patients, the majority of whom had cardiovascular procedures, were studied. The Haemonetics Cell Saver (Fig. 1) was employed as an intraoperative scavenger of blood that was shed at elective/emergency surgical procedures and/or as a processor of blood remaining in the pump following cardiopulmonary bypass.

Blood is retrieved from the operative site by suctioning into a double-lumen catheter, in which it is anticoagulated immediately with heparin (60,000 U heparin/1000 ml of physiologic saline). Figure 1 schemati-

Presented at the Ninety-fourth Annual Meeting of the Southern Surgical Association, December 6–8, 1982, Palm Beach, Florida.

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Submitted for publication. December 13, 1982.

0003-4932/83/0500/0536 $01.10

cally depicts the method by which salvaged blood is then diverted to a collection reservoir where a macro-filter of 180 microns removes gross debris. Thereafter the filtered blood is pumped to a spinning centrifuge bowl where it is packed, washed with normal saline, and concentrated to a hematocrit above 50%. The effluent containing plasma fractions, platelets, leucocytes, free hemoglobin, anticoagulant, saline, and other small debris is discarded. The washed packed red blood cells, suspended in saline, are pumped from the centrifuge bowl to a parent reinfusion bag. From this receptacle, packed cells are removed to a transfer pack, labeled appropriately, and, through a micro-filter of either 20 or 40 microns, are immediately reinfused into the patient. If bleeding is brisk, the entire process from collection to reinfusion requires an average 8 to 10 minutes.

All reagents and software are sterile and disposable. A minimum of 750 cc normal saline is used to wash each bowl of blood, a volume of about 225 cc of packed cells. A manual hematocrit, visual hemolysis check, and microbiologic culture is performed during the operative period on at least one unit in each procedure. Early in the study, a series of coagulation profiles and plasma hemoglobin determinations on the prepared autologous product repeatedly failed to reveal any evidence of plasma or heparin. In circumstances in which the blood was not used in the operating room, it was stored in the blood bank for use within 4 hours of collection. The time before expiration after such storage will be lengthened to 24 hours. Pump blood processing is performed in the same manner, except herein there is a direct attachment between the pump and the Cell Saver.

Extensive studies of coagulation before and after the Cell Saver usage have become standard with all cardiac and vascular cases and essentially all other patients in this series. They include pre- and post-surgical evaluation of platelet count, prothrombin time (PT), activated partial thromboplastin time (PTT), fibrinogen, and antithrombin III (AT-III). Additional tests included protamine sulfate paracoagulation, fibrin degradation products, and euglobulin clot lysis, which were performed when coagulation abnormalities were apparent in any of the aforementioned standard studies and in the rare instances in which the patient had a clinically obvious defect in hemostasis.

Strict aseptic technique was followed by all members of the Cell Saver team who are medical technologists operating under the supervision of the medical director of the blood bank. Twenty-four hour daily coverage has been provided.

Results

In 648 (89.4%) surgical patients, the Cell Saver was used as an intraoperative scavenger and/or processor of blood remaining in the pump after cardiopulmonary bypass and other vascular procedures. A majority of the cases were cardiothoracic-vascular (Fig. 2), among which 65% were coronary artery bypass (Table 1). The miscellaneous category included exploratory laparotomy, hysterectomy, Caesarian section, ectopic pregnancy, and others and comprised 5.9% of the series. Finally, 4.7% of the procedures were orthopedic, involving total hip replacement and scoliosis repair.

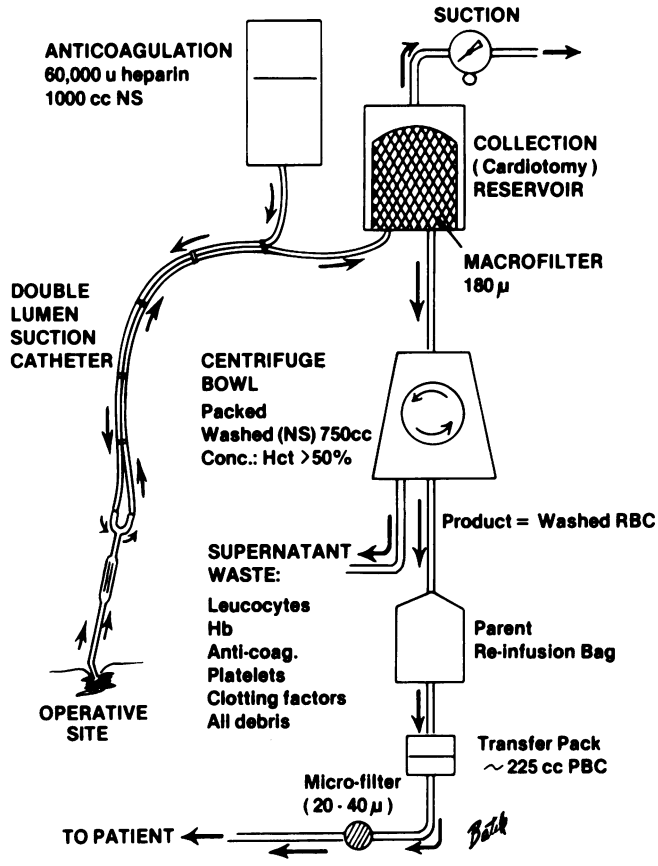

FIG. 1. Schematic of Haemonetics Cell Saver® with modifications.

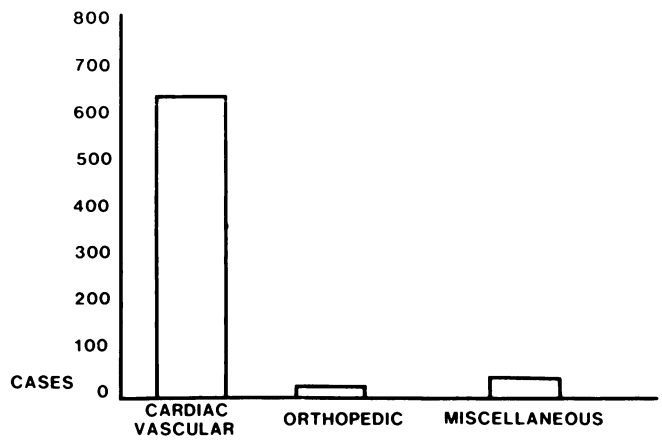

FIG. 2. Categories of patients operated utilizing the Cell Saver®.

TABLE 1. *Case Distribution Utilizing Cell Saver*

	No.	(%)
I. Cardiac-vascular cases	648	(89.4)
Coronary artery bypass	471	(65.0)
Valve replacement, aortic, mitral, tricuspid	61	(8.4)
Patent ductus and atrial septal defect	7	(0.9)
Aneurysm	90	(12.4)
Aortic graft	19	(2.6)
II. Orthopedic	34	(4.7)
III. Miscellaneous	43	(5.9)
Total	725	(100.0)

In this study, men predominated in a ratio of 2.8:1, with the mean age for the total series being 52 years (Fig. 3). The Cell Saver was used rarely for children following trauma.

The mean washed red blood cell yield for the total series was 573 cc with a mean hematocrit value of 55 cc/dl. Analysis of the product salvaged in the three patient categories is illustrated in Figure 4. Three cases merit special comment. In a patient undergoing abdominal aneurysm repair, a total of 3825 ml of washed red blood cells with an average hematocrit of 61% was retrieved. In two procedures, one a thoracic aneurysm and the other a quadruple coronary artery bypass, two Cell Savers® were used simultaneously, with the recovery of 4300 cc and 1800 cc of washed red blood cells, respectively. No clotting aberrations were observed in the intraoperative or postoperative periods, and all three patients survived.

An analysis of intraoperative red blood cell usage (packed cells, washed frozen red blood cells, and/or whole blood) disclosed that a mean of 1.97 units of bank blood (SD = 1.47) was used before the Cell Saver® era, compared with 0.75 units (SD = 1.18) after initiation of auto transfusion with this sytem (Figure 5). This reduction represented a statistically significant decline ($p < 0.001$) in the use of homologous blood products.

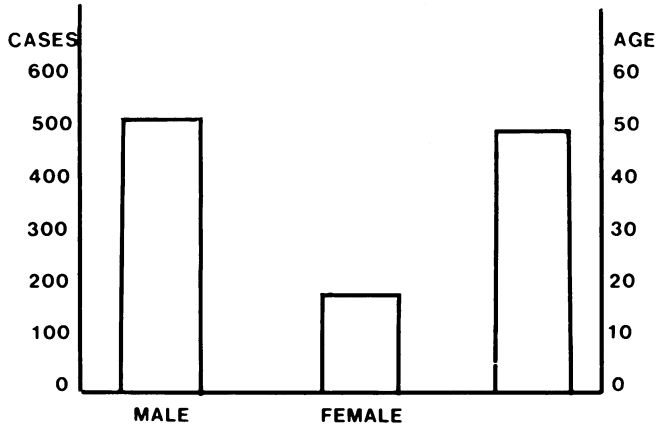

FIG. 3. Mean age and sex of patients.

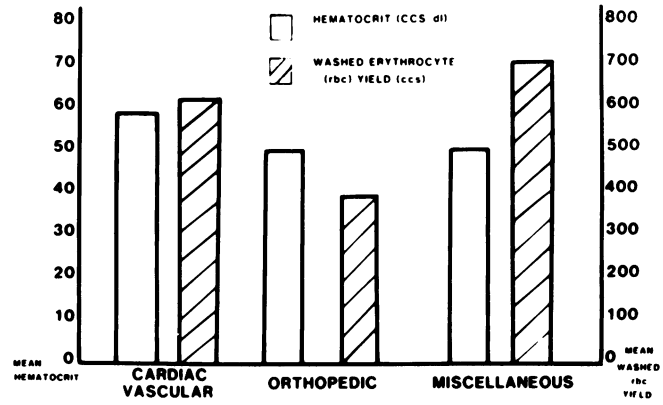

FIG. 4. Mean hematocrit and amount of product in various patient categories.

In cardiovascular patients, extensive testing of various coagulation parameters in the preoperative period and in the postoperative state have become routine with usage of the Cell Saver® at this institution. Results with the PT and PTT, AT III and fibrinogen, before and after operation, in 25 typical cases revealed no gross deviation from normal values (Figure 6).

Some coagulation statistics are available for the period before the Cell Saver® was used and, while a primary coagulopathy like DIC was exceedingly rare in the group studied, no valid comparisons between the two periods can be drawn. Most importantly, in no instance could a defect in hemostasis be attributed to the use of autologous transfusion.

Microbiologic cultures of at least one unit of washed packed cells prepared during operation were performed. While, on occasion, *Staphylococcus epidermidis* and/or diphtheroids were observed in bacteriologic cultures, there was no evidence of clinical sepsis ascribed to these organisms in any patient in the study. In one case in which a small bowel infarction was noted at operation,

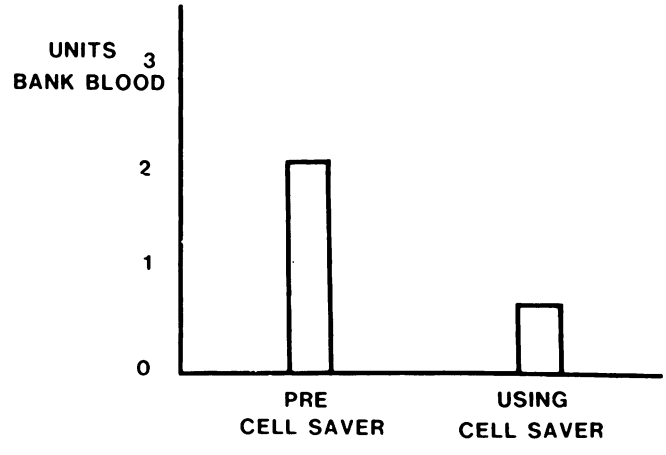

FIG. 5. Intraoperative red blood cell usage in 100 cases in the pre- and post-Cell Saver eras.

an anaerobe, *Propionibacterium,* was present in blood cultures. The same organism was present, however, in the patient's blood before operation and was also present in peritoneal cultures taken during surgery.

The mortality rate for the entire series of 725 patients was 2.8%. The majority of the deaths in these 20 patients occurred within 24 hours of the surgical procedure. In none of the 20 patients was morbidity or mortality influenced by the autotransfusion technique employed.

Discussion

Autologous blood, as a transfusion product, offers numerous, significant advantages over the conventional homologous bank blood. As autologous blood is the only perfectly compatible blood, it abolishes the possibility of transmission of diseases, especially viral hepatitis, and immunization of the recipient against erythrocyte and other blood antigens of the donor. Further, autologous transfusion abrogates graft-versus-host reactions. In most series in which this product has been used, a marked reduction in febrile, allergic, and hemolytic reactions was observed. Importantly, bank blood stores are conserved.[1-5,9] Compatibility testing and identification errors are virtually eliminated. Also, it will be accepted occasionally by those whose religious convictions will not allow them to receive homologous blood products.[7]

Whether preoperative with pre-stored deposits, perioperative with hemodilution techniques, or intraoperative or postoperative with salvage, autologous blood transfusion has aroused considerable interest and demonstrated a large measure of success in recent years.[10-16]

Of special concern has been the retrieval of blood lost at surgery or immediately following trauma. Although the concept of such autotransfusion dates back over 150 years, it has only been in the last decade that efficient, technologic advances have allowed safe recovery, such that reinfusion of autologous blood has been feasible.

Several techniques have facilitated this progress. The earlier autotransfusers, in which whole blood had been saved and reinfused, have shown significant side effects in the recipient. Among these are marked increases in the plasma hemoglobin secondary to administration of hemolyzed cells, serious hemostatic defects either from dilution of procoagulants or primary activation of coagulation or fibrinolysis, air embolism, and occasional renal failure.[6,7,8] Additionally, to forestall clotting, these older techniques often depend on systemic anticoagulation with heparin or citrate. This is particularly undesirable in the management of the actively bleeding patient. Even so, the literature is replete with testimony favoring the use of autotransfusion of whole blood, especially in the setting of massive hemorrhage during operation or following trauma.[1-3,15]

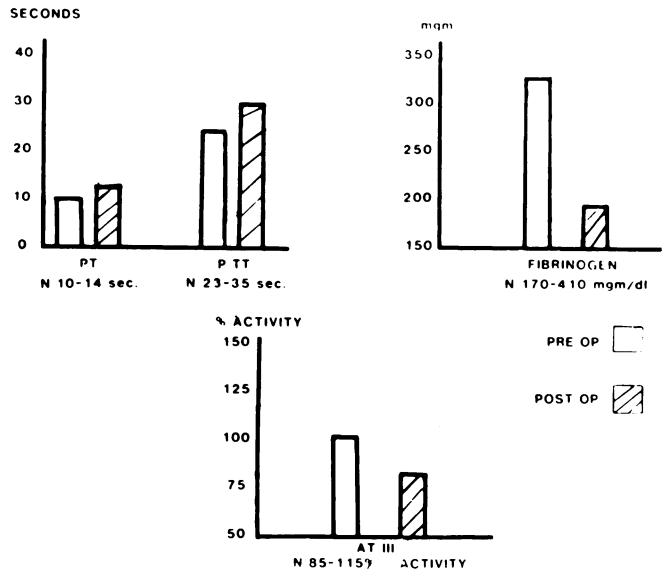

FIG. 6. Coagulation values before and after operation in 25 cases in which the Cell Saver® was used.

The Haemonetics Cell Saver, introduced six years ago, has corrected most of these difficulties.[17] With this apparatus, the blood shed at the operative site is diverted by suction into the extracorporeal system, where it is heparinized, filtered, washed with sterile saline, and emerges for return within ten minutes of bleeding as packed erythrocytes suspended in physiologic saline. Used as directed by Haemonetics, the finished product is devoid of extraneous material including free hemoglobin, myoglobin, bone particles, fat, heparin, activated clotting factors, and cellular debris. Modifications of the procedure have been studied to accommodate its use in massive blood loss.[18]

Thus, there is a significant difference between the Cell Saver and the prototype of the earlier models, the Bentley Autotransfuser®. The latter device has been used frequently in trauma with massive blood loss. Blood is removed from the site of loss, heparinized, passed through a macrofilter to remove large clots, and directly reinfused to the patient. This filter does not remove material such as activated clotting and complement factors, fatty particles, platelet aggregates, hemolyzed red blood cells, and other debris. When blood containing such particulate matter is directly reinfused into the patient, the lungs can become embolized. Renal impairment can also ensue secondary to the hemoglobinuria that results when large amounts of plasma hemoglobin from the hemolyzed red blood cells are thus transfused. Air embolism and major coagulopathies are other undesirable side effects that are not uncommon. The Cell

Saver, on the other hand, delivers only a washed red blood cell product of high hematocrit to the patient. No anticoagulants, particulate matter or air, activated clotting factors, or extraneous material are returned.

The present study is a retrospective review of 725 surgical cases in which intraoperative autologous transfusion was accomplished using this instrument. The mean yield for the entire series was 573 cc of washed red blood cells with a mean hematocrit of 55 cc/dl. Importantly, homologous bank blood used during operation declined over 50% with the use of the Cell Saver. This is consistent with results published in another study.[19]

Although the patients often represented a high risk category, the overall mortality was only 2.8%, with most of the 20 individuals dying within 24 hours of surgery. In no instance was morbidity or mortality influenced by the autotransfusion. Conspicuously absent from this series is any evidence of a major coagulopathy, systemic sepsis, air or particulate embolism, renal failure, or any serious sequelae secondary to use of the autotransfusion. This can be attributed partially, as stated previously, to the scrupulous monitoring of the procedure to prevent such adverse complications.

Pre- and postoperative hemostasis evaluation of the group has been comprehensive. Quality control measures used in each case to achieve product safety included the determination of hematocrit, evaluation for evidence of hemolysis, and microbiologic cultures. The experience with nonpathogenic organisms, recovered from intraoperative culturing, most likely reflects environmental factors reported in previous studies.[20] Standard use of antibiotics after operation in all of these high risk patients doubtlessly protect them from risk incurred by the presence of such microorganisms.

The skill of the team should be mentioned. Lack of such operators has been mentioned earlier as a serious deterrent to the use of the Cell Saver.[21,22] The expertise of the group, composed of medical technologists, reflects their considerable blood banking experience and extensive training. Working under the physician director of the blood bank, they provide 24-hour daily coverage of the Cell Saver. Furthermore, since they assume total responsibility for operation of the Cell Saver, the surgeons, anesthesiologists, nurses, and pump team are freed from any involvement with the procedure.

With cost as the sole consideration, it is apparent that since the price of one unit of compatibility tested blood in this institution is $70 and the use of the Cell Saver is approximately $300, the procedure becomes cost-effective when there is a need to transfuse four or more units of bank blood. This, of course, does not even consider the fact that autologous blood products are far superior to the homologous ones.

In summary, this experience with intraoperative use of the Cell Saver in 725 surgical patients provides ample proof that this newer technique of autologous transfusion is exceedingly safe, highly efficient, and, in some settings, even life-saving.

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